Using NI FlexRIO to Develop a High-Speed, Compact OCT Imaging System

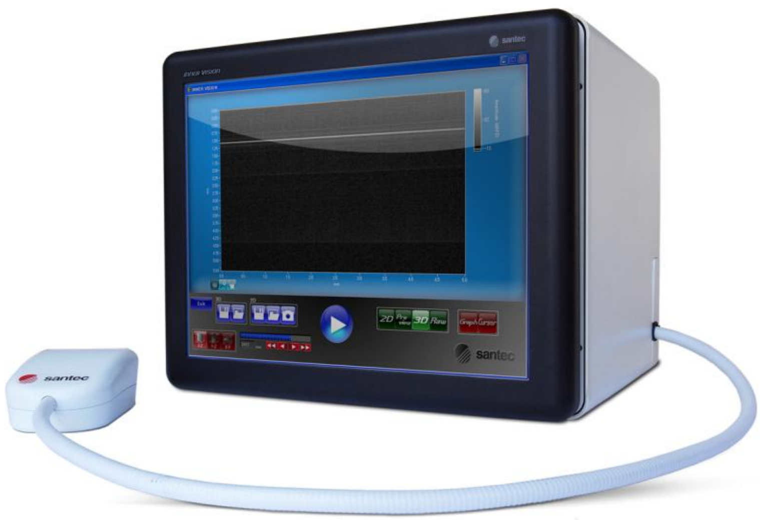

Figure 1. The portable OCT system from Santec uses FPGA-based image processing.

"With our conventional system, we were limited to slower image display rates because of the computationally intensive processing required to create the image. Using the NI FlexRIO platform and moving to FPGA-based processing, we achieved an imaging speed-up of 4X and significantly reduced the size of our system."

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The Challenge:
Increasing the imaging speed and reducing the size of an optical coherence tomography (OCT) imaging system.

The Solution:
Using NI FlexRIO and field-programmable gate array (FPGA) technology to create an OCT system that achieved a 4X speed increase and a dramatically smaller footprint compared to our previous solution.

OCT is a noninvasive imaging technique that enables visualization of tissue or other objects with resolution similar to that of some microscopes. There has been an increasing interest in OCT because it provides much greater resolution than other imaging techniques such as magnetic resonance imaging (MRI) or positron emission tomography (PET). OCT uses a low-power light source and the corresponding light reflections to create images, which is a method similar to ultrasound that uses light instead of sound.

In Swept Source-OCT (SS-OCT) applications, a laser scans a sample while a fast analog-to-digital converter (ADC) acquires data, and processing yields a tomography image. As a result, the system must be capable of high-speed acquisition, complex image processing, and accurate control of the laser scanning. In addition, the acquisition and control portions of the system must be tightly synchronized to achieve good performance.

Our Conventional System

In an OCT system, obtaining the final image requires significant processing including fast Fourier transforms (FFTs), interpolation, and DC offset calculations. Traditionally, this processing happens in software running on the host computer, which can be time consuming and affect the overall imaging speed of the system. Tuning of the laser is usually performed in software as well, further burdening the CPU. In our conventional system, we realized the time needed for data processing allowed us to achieve an image display rate of only 10 frames per second, even though other parts of the system may have been capable of running faster.

Figure 2 shows the conventional system configuration, which requires two devices to acquire the image data and control the laser scanner. Because there are two boards in the system, it leads to more complex wiring.

Fast image display rates are required to measure objects that move quickly, such as human organs or objects in motion. There is also a delay between acquiring the data and displaying it. Off-the-shelf PCs could not provide sufficient processing for the imaging performance we needed and also increased the cost of the system. All of these factors helped drive the need for a new system.

Next-Generation Solution

To prototype our new architecture, we used NI FlexRIO modular FPGA hardware programmed with the NI LabVIEW FPGA Module, a graphical design language that allows the FPGA circuitry to be designed without needing to know VHDL coding. NI FlexRIO combines interchangeable, customizable I/O adapter modules with a user-programmable FPGA module in a PXI or PXI Express form factor.

For the I/O, we used a custom adapter module that combined the high-speed ADC (100 MS/s, 12-bit resolution) for acquisition with the digital-to-analog converter (DAC) circuitry (50 kS/s, 12-bit resolution) for the laser scanner control. By prototyping the new system using NI FlexRIO, we were able to quickly get a working solution and determine if changes were needed. Algorithms were initially developed using LabVIEW on the host side (FFTs, interpolation, and DC offset), and after proving the algorithms, they were moved over to the FPGA to accelerate the processing performance. Also, we quickly determined the required hardware modifications because the I/O was decoupled from the FPGA back end, which provided the PCI Express interface to the host PC. After we had the hardware and firmware proven out, we moved to a more deployable PCI Express board with the same specifications with much higher confidence of success. Figure 3 shows our new system configuration.

Achieving Faster Processing and Reducing System Size

After acquiring the data, it is processed in the FPGA and sent back to the PC. We saw a significant speed-up when we moved processing to the FPGA from the PC, which enabled significant improvement in video display rates. In contrast to the previous image display rate of 10 frames per second, we achieved a rate of 40 frames per second with the new FPGA-based system configuration, or a 4X performance improvement.

Our system can now image objects that move quickly, including human organs and other moving samples. Also, the new FPGA-based system provides real-time measurement signal processing, which improves display performance by eliminating the lag between measurement and display. Figure 4 shows a LabVIEW front panel for the imaging system.

In the conventional system configuration, we needed two devices – a digitizer for data acquisition and a D/A board to control the scanner. We also needed additional cabling to synchronize the devices. With our new platform, we combined the acquisition and control I/O in a single module and synchronized both functions using the FPGA, so it is easier to build, cable, and configure the system. In addition, we saved space because we no longer require external wiring.

Because of the size reduction, we can carry the entire system by hand, which opens the product up to new applications in a variety of spaces.

Conclusion

With our conventional system, we were limited to slower image display rates because of the computationally intensive processing required to create the image. Using the NI FlexRIO platform and by moving to FPGA-based processing, we achieved an imaging speed-up of 4X and significantly reduced the size of our system.

In the past, we needed a powerful computer for data processing; using an FPGA for processing purposes reduces our dependency on computer capability. We can lower the cost of the system and use a laptop or low-powered CPU board, which has the added benefit of addressing new markets that require a smaller, low-cost system. In addition, using LabVIEW FPGA, we can make future FPGA modifications or customizations for specific customer needs, saving us development time and cost.

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